

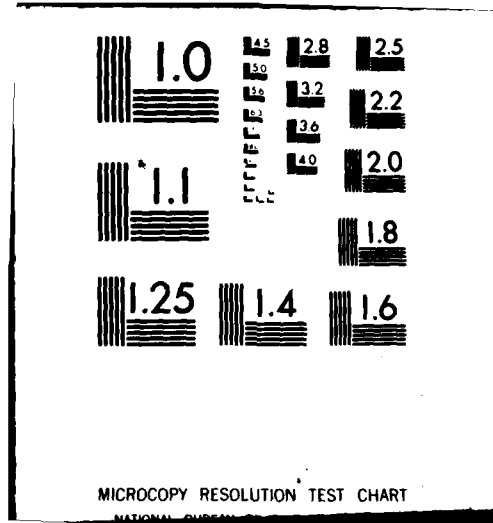
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STUDY OF THE FREQUENCY ASSIGNMENT CONGESTION IN THE ULTRA HIGH --ETC(U)
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Systems Research &
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Study of the Frequency Assignment Congestion in the Ultra High Frequency Air Traffic Control Air/Ground Communication Band

Charles W. Cram

April 1982

Final Report

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16. Abstract To provide air traffic control of military aircraft operating in the National Airspace System, the Federal Aviation Administration (FAA) makes use of frequencies in the 225 - 400 MHz (UHF) band which is normally administered by the Department of Defense. In 1970 the Military Communications and Electronics Board (MCEB) announced their intention to implement 25 kHz channel spacing in the UHF band. In 1976, the MCEB published an implementation plan which allotted 274 channels for use by the FAA for air traffic control. The purpose of the following study is to determine if the 274 channels made available will be sufficient to satisfy existing and future communication requirements for air traffic control of military aircraft. The study will also show how much additional spectrum support would be required if the 274 channels allotted are not sufficient and possible geographic areas where this additional support would be most necessary. To make such long range frequency assignment plans, the FAA makes use of automated frequency assignment models developed and operated for the FAA Spectrum Management Branch by the Electromagnetic Compatibility Analysis Center. With these assignment models, different assignment strategies can be simulated and the impact of each strategy on the spectrum available to ATC communications can be compared to determine the best course of action.					
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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
y	yards	9	meters	m
mi	miles	1.6	kilometers	km
AREA				
sq in	square inches	6.5	square centimeters	cm ²
sq ft	square feet	0.09	square meters	m ²
sq yd	square yards	0.8	square meters	m ²
sq mi	square miles	2.6	square kilometers	km ²
ac	acres	0.4	hectares	ha
MASS (weight)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
short tons (2000 lb)	short tons	0.9	tonnes	t
VOLUME				
cup	teaspoons	5	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cup	0.24	liters	l
qt	quarts	0.97	liters	l
gal	gallons	3.8	liters	l
cu ft	cubic feet	0.03	cubic meters	m ³
cu yd	cubic yards	0.76	cubic meters	m ³
°F	Fahrenheit temperature	5/9 after subtracting 32	Celsius temperature	°C

* For more complete conversion factors, including tables, see *Math, Science, and Technology*, 1980, by the U.S. Department of Commerce, Office of Technology Assessment, NIST, Gaithersburg, MD 20899.

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
km	kilometers	1.1	miles	mi
mi	miles	0.6	miles	mi
AREA				
cm ²	square centimeters	0.16	square inches	in ²
m ²	square meters	1.2	square yards	yd ²
km ²	square kilometers	0.4	square miles	mi ²
ha	hectares (10,000 m ²)	2.5	acres	ac
MASS (weight)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	st
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m ³	cubic meters	35	cubic feet	ft ³
m ³	cubic meters	1.3	cubic yards	yd ³
TEMPERATURE (exact)				
°C	Celsius temperature	5/9 (then add 32)	Fahrenheit temperature	°F



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Availability Codes	
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1. BACKGROUND AND PURPOSE

To provide air traffic control (ATC) of military aircraft operating in the National Airspace System, the Federal Aviation Administration (FAA) makes use of frequencies in the 225 - 400 MHz (UHF) ^{1/} band which is normally administered by the Department of Defense (DOD). In 1970 the DOD Military Communications and Electronics Board (MCEB) announced their intention to implement 25 kHz channel spacing in the UHF band. In 1976, the MCEB published an implementation plan which allotted 274 channels (See Appendix A) for use by the FAA for air traffic control. [3] The purpose of the following study is to determine if the 274 channels made available will be sufficient to satisfy existing and future communication requirements for air traffic control of military aircraft. The study will also show how much additional spectrum support from the military would be required if the 274 channels allotted are not sufficient and possible geographic areas where this additional support would be most necessary.

2. DESCRIPTION OF THE ASSIGNMENT MODEL

To make long range frequency assignment plans, the FAA makes use of automated frequency assignment models developed and operated for the FAA Spectrum Management Branch by the Electromagnetic Compatibility Analysis Center (ECAC). With these assignment models, different assignment strategies can be simulated and the impact of each strategy on the spectrum available to ATC communications can be compared to determine the best course of action. The UHF assignment model is an extension of the VHF assignment model which was used to plan the implementation of 25 kHz channel spacing in the 118 - 136 MHz band.

a. Assignment Criteria

(1) The frequency assignment models base their calculations on standard FAA assignment criteria. ^{2/} Cochannel assignments must be afforded a 14 dB signal ratio at the victim aircraft receiver between the desired ground-to-air signal and the undesired air-to-air signal from an aircraft in another service volume. The service volumes of adjacent channel assignments (frequencies offset by one channel width for assignments with like channel spacing) must be separated by 2 nmi (3.7 km). Since there is a mixture of 50 kHz and 25 kHz equipment in the environment during the transition to 25 kHz channel spacing, 50 kHz receivers must be protected from interfering

^{1/} According to the standard definition, the Ultra High Frequency (UHF) band comprises frequencies from 300 - 3000 MHz. However, within the aviation community, and thus for the purposes of this report, the 225 - 400 MHz band is referred to as the UHF band.

^{2/} FAA Order 6050.4 which details FAA's frequency assignment criteria in the UHF band has been recently revised. Modifications in the adjacent channel and interleaving criteria were made, however these changes should have little, if any, impact on the results of this study.

transmissions offset by 25 kHz (25 kHz interleaving). The FAA assumes that a receiver designed for 50 kHz channel spacing will provide 6 dB of rejection to a signal offset by 25 kHz. Therefore, assignments offset by 25 kHz are afforded 8 dB of protection by geographic separation. This is equivalent to the 14 dB obtained in the cochannel case. Together, these three analyses are referred to as the intersite analysis. The intersite analysis for the VHF and the UHF assignment models are basically the same.

(2) Interference interactions between facilities located at or near the same site are as much of a problem as the intersite interference interactions discussed above. ATC communication channels located at the same site must be separated in frequency by at least 500 kHz. For the computer model, the site is defined as having a radius of .2 nmi (.4 km). To avoid intermodulation interference, all two signal third order intermodulation products of nearby FM, TV, and VHF and UHF communication/navigation frequencies are calculated. Any UHF ATC communication frequency which coincides with an intermodulation product will not be considered for assignment at the site. To avoid harmonic interference, the second and third order harmonics of FM, TV, and VHF ATC communication/navigation frequencies in the area are calculated. Again, if a harmonic coincides with a UHF ATC communication frequency, that frequency will not be considered for assignment at the site. For the intermodulation and harmonic analyses, FM and TV stations within 15 nmi (27.6 km) and VHF ATC communication/navigation frequencies within 2 nmi (4 km) of the site are considered. The above adjacent signal, harmonic, and intermodulation analyses are basically the same as those in the VHF assignment model. The UHF assignment model has an additional section to account for non-FAA assignments in the UHF band which often have different emissions, bandwidths, and power levels than those used for ATC communications. Frequencies which cannot be assigned because of non-FAA systems are determined by considering the bandwidth, modulation type, and power of these systems, in conjunction with the proximity of the area of operation of the system to the service volume of the affected ATC communication facility. The distance at which to search for these systems is dependent upon power level and emission, and is limited to either line-of-sight or a fixed radius supplied by the user. Together, the adjacent signal, harmonic, and intermodulation analyses and the analysis of non-FAA systems form the cosite analysis. The intersite and cosite assignment criteria remain constant except when testing the effect of a change in criteria.

b. Assignment Data Base

(1) The intersite and cosite analyses require an extensive data base. Two data files, the requirements file for the intersite analysis and the background file for the cosite analysis, were developed drawing on information from a wide range of sources. The requirements file contains the existing UHF ATC communication assignments operated by the FAA in the contiguous United States. Information for this file is drawn from the Government Master File (GMF) which is compiled and maintained by the Interdepartment Radio Advisory Committee (IRAC). En route frequency records contain the coordinates of their associated multipoint tailored service

volumes. This information is extracted from the FAA's Adaptation Controlled Environment System (ACES) tapes supplied by each ATC center. The background file contains all the FM, TV, VHF/UHF communication/navigation frequencies, and non-FAA UHF systems required for the cosite analysis.

Sources for the background file are:

VHF/UHF Com/Nav, 108 - 136 MHz -- IRAC Government Master File
225 - 400 MHz

Non-FAA UHF Systems -- IRAC Government Master File

FM and TV, 54 - 108 MHz -- Data tape supplied by the FCC
174 - 216 MHz

VHF Operational Control, 128.8 - 132.0 MHz -- ARINC data tape

Different assignment strategies can be simulated by manipulating the data base, the available frequencies, the allowable channel spacing, and the order of assignment. The impact of different strategies can then be compared to determine the most advantageous assignment plan. By adding a list of future frequency requirements to the data base, the impact of the expected growth in the number of channels required can be assessed.

(2) When planning the implementation of 25 kHz channel spacing in the VHF band, a VHF data base was already compiled and available at ECAC to use. However, to perform the following study of the UHF band, a data base of current UHF assignments had to be compiled. The requirements file was obtained by selecting from the IRAC GMF all records with FAA identification codes plus any other records of facilities currently using frequencies designated by the MCEB for FAA use (Appendix A). The resulting data base has 2901 records, 654 high altitude en route, 695 low altitude en route, and 1552 terminal assignments. These numbers do not include assignments on the UHF Flight Service Station frequency, 255.4 MHz, emergency channel guard assignments on 243.0 MHz, or Backup Emergency Communication assignments. To simplify the generation of the requirements file, all facilities were assumed to have circular service volumes. The background file was obtained by compiling all unclassified records in the GMF for the 225 - 400 MHz band and merging these with the VHF background file. Anticipated future requirements added to the data base will be discussed in Section 4.

3. ANALYSIS OF THE EXISTING ENVIRONMENT

a. The first objective of this study is to determine if the 274 frequencies allotted to the FAA are sufficient to satisfy all existing ATC UHF frequency requirements. Figure 1 is a compilation of FAA's current use of the UHF band. [9] As indicated in this figure, the FAA is able to use only 132 of their allotted frequencies because many military aircraft are not yet equipped to operate on 50 kHz and 25 kHz spaced channels. This tends to aggravate the problems of frequency assignment and congestion in this band.

FIGURE 1
Current FAA Usage of the
225 - 400 MHz Band
As of June 1981

<u>Function</u>	<u>Number of Assignments</u>	
Air Traffic Control		2901
High Altitude En Route	566	
Low Altitude En Route	695	
Terminals	1552	
High Altitude Tactical	88	
Special Use		
Backup Emergency Communications (BUEC)		712
UHF Emergency Guard (243.0 MHz)		571
UHF Flight Service Station (255.4 MHz)		<u>351</u>
	Total	4535

All Current FAA UHF Assignments are on 100 kHz Spaced Increments

132 FAA Channels Used For 1741 Air Traffic Control Assignments

299 Non-FAA Channels Used For 1160 Air Traffic Control Assignments

b. The analysis of the existing environment is based on the assumption that all 274 FAA frequencies are available for assignment, that all receivers are 25 kHz capable (the interleaving criteria was not then necessary), and that the search radius for non-FAA systems was limited to 200 nmi. The following basic strategies were then applied:

1. All requirements in the data base were assigned on FAA allotted frequencies with no preference given to a particular type of facility. The order of assignment was determined by the relative density of frequency requirements.
2. All requirements in the data base were assigned on FAA allotted frequencies with high altitude en routes assigned first, low altitude en routes second, and terminal facilities last.

Strategy 1 simply shows the effect of a total reassignment of requirements on to FAA frequencies. Strategy 2 is similar to strategy 1 but also reflects the current FAA policy of giving preference to en route requirements when assigning FAA frequencies since they are more difficult to protect from interference than are terminal requirements. Strategies 1 and 2 were then repeated to determine the number of additional channels necessary to satisfy requirements that could not be assigned on FAA frequencies. Each strategy was also tested several times to determine the effects of changes in cosite criteria and of how certain special types of facilities were assigned.

c. Figure 2 is a compilation of results obtained from a study of the existing frequency environment.

FIGURE 2
Results of the Study of the Existing
Frequency Environment

<u>Assignment Study Number</u>	<u>Description</u>	<u>Requirements To Be Assigned</u>	<u>Number Not Assigned</u>	<u>Number of Channels to Complete</u>
1	All requirements assigned on FAA frequencies. Ordering by Density	2901	243	115
2	All requirements assigned on FAA frequencies. Order - H, L, then T	2901	179	84
3	Same as 2 but non-FAA assignments eliminated, local controls and TSU's preassigned on existing frequencies.	2566	56	39
4	Same as 1 but non-FAA system portion of cosite analysis disabled.	2901	215	*

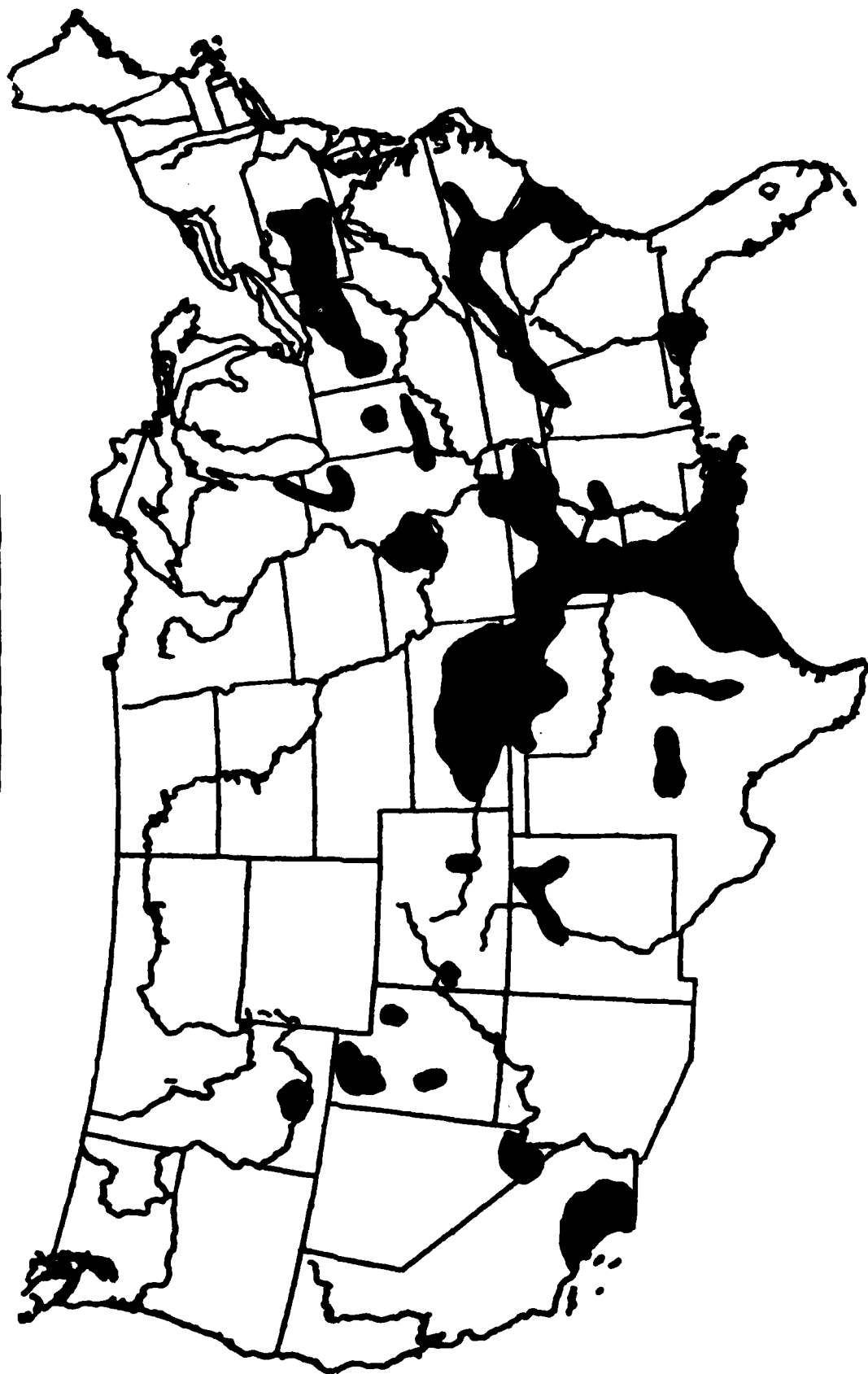
* Value not determined

d. Assignment #1 indicates that even with all 274 frequencies available many requirements could not be satisfied unless additional channels were made available to the FAA. By changing the assignment order so that en route requirements were given preference over terminal requirements for assignment on FAA frequencies (Assignment #2), a decrease in the number of unassigned requirements resulted. More importantly, since more terminal assignments can be accommodated on a single frequency than en route assignments, fewer additional channels were required to assign the remaining requirements (all 179 requirements not assigned were terminal requirements). Many of the 2901 requirements in the data base are for facilities which are eligible for only certain frequencies. For example, High Altitude Tactical Special Use (TSU) facilities must be assigned on 296.7, 321.3, 364.8, or 369.9 MHz. Local control (tower) facilities are commonly assigned on 257.8 MHz. The data base also contains 74 non-FAA assignments currently on FAA frequencies. These must either be assigned on their existing frequencies or moved to other non-FAA frequencies in the band. Assignment #3 shows the improvement which results by handling these requirements in a similar fashion to current FAA procedures. Assignment #3 most closely models the assignment policy which would probably be followed if all 274 channels were available for assignment. Assuming these constraints, all existing frequency requirements could be satisfied with much less additional spectrum support (39 additional channels versus the existing 299) from the military.

e. An examination of the results for Assignment #1 was made to determine those areas of the country where it was hardest to assign UHF frequencies. Figure 3 is an illustration of where these areas are located. Bear in mind that this is not a density plot of UHF facilities. Since the assignment model attempts to assign the most difficult first, some areas of high UHF frequency assignment density such as New York and Norfolk, Virginia do not appear. However, areas immediately adjacent are indicated because the available frequencies were already assigned in the high density areas. Some of the smaller areas on the map may disappear and others may appear if the assignment order or criteria were changed. However, the larger areas along the Gulf coast and in Arkansas, Oklahoma, Kansas, Ohio, Missouri, North Carolina, and California can be expected to remain. Making assignments in these areas will continue to be a problem in the future.

f. The major difference between the UHF and VHF assignment models is the extensive treatment by the UHF model of non-FAA systems within the UHF band. The protection criteria used to determine if non-FAA systems are a potential source of interference are more conservative than the other cosite criteria. Assignment #4 was performed to determine if this section of the cosite model was overly restricting assignments on FAA frequencies. Only 28 additional assignments could be made if this portion of the cosite model were disabled. Therefore, from a utilization standpoint, it was decided that the extra interference protection obtained was not causing undue burden on the available spectrum.

FIGURE 3
Areas of the Country Where It Is Most
Difficult to Assign UHF Frequencies
(Based on Assignment #1)



4. ANALYSIS OF THE FUTURE ENVIRONMENT

The second objective of this study is to determine whether the 274 frequencies allotted to the FAA will be sufficient to satisfy future requirements for UHF facilities. The impact of future requirements depends upon their number, location, and service volume size. How these parameters were derived is described below.

a. Number of Future Requirements

1) Comparison of VHF and UHF. The number of UHF requirements is tied very closely to the number of VHF requirements. In most sectors, air traffic controllers simulcast on a VHF and a UHF channel so that their message may be heard by both civilian and military aircraft under their control. A comparison of the VHF and UHF data bases as of June 1981 (See Figure 4) reveals that the number of VHF and UHF en route assignments correlates very well, while there is a significant difference in the number of terminal assignments.

FIGURE 4
Comparison of the VHF and UHF Data Bases

	<u>High Altitude</u> <u>En Routes</u>	<u>Low Altitude</u> <u>En Routes</u>	<u>Terminals</u>
VHF	549	680	2200
UHF	566*	695	1552

* Does not include 88 Tactical Special Use Facilities

The difference in the number of terminal assignments is due to the fact that not all smaller airports having a control tower have a UHF channel assigned. An examination of the United States IFR Supplement [2] shows that in the major terminal areas, there is a one-to-one correspondence between the number of VHF and UHF channels while 82% of the smaller terminal areas having one or more VHF assignments have at least one UHF channel.

2) Expected Growth. Since the number of UHF requirements is so closely related to the number of VHF requirements, the expected number of future UHF requirements was developed from the growth of the number of VHF requirements projected when the implementation of 25 kHz channels spacing in the VHF band was planned. [1] In the VHF study, a 4% per year rate of growth was predicted for en route and terminal facilities through 1985. ^{3/} From the 4% rate of growth the number of future VHF requirements was predicted (See Figure 5).

^{3/} The accuracy of this prediction made in 1978 can be confirmed by comparing the June 1981 VHF data base with an interpolation between the 1981 and 1982 VHF predictions:

	<u>Highs</u>	<u>Lows</u>	<u>Terminals</u>
Actual June 1981	549	680	2200
Predicted June 1981	525	675	2260

FIGURE 5
Number of Future VHF Requirements
From 1979 Through 1987

<u>Year</u>	<u>High</u>		<u>Low</u>		<u>Terminals</u>	
	<u>En Routes</u>	<u>Change</u>	<u>En Routes</u>	<u>Change</u>		<u>Change</u>
1979	475		612		2049	
1980	494	19	636	24	2131	82
1981	514	20	661	25	2216	85
1982	535	21	687	26	2305	89
1983	556	21	714	27	2397	92
1984	578	22	743	29	2493	96
1985	601	23	773	30	2593	100
1986*	625	24	804	31	2697	104
1987*	650	25	836	32	2804	107

* Not included in the VHF Study. Table has been extended so the UHF Study would cover 5 years.

For the UHF study, the June 1981 UHF data base was assumed to be the base line and UHF requirements were added each year to reflect a one-to-one correspondence with the change in VHF requirements for en route and major terminal facilities. In the VHF study each small terminal facility was assumed to have a requirement for two frequencies. For the UHF study 82% of the small terminal areas used in the VHF study were assumed to have a requirement for one UHF channel. Figure 6 shows the predicted growth of requirements in the UHF band.

FIGURE 6
Number of Future UHF Requirements
From 1981 Through 1987

<u>Year</u>	<u>High</u>		<u>Low</u>		<u>Terminals</u>	
	<u>En Routes</u>	<u>Change</u>	<u>En Routes</u>	<u>Change</u>		<u>Change</u>
1981	566		695		1552	
1982	587	21	721	26	1624	72
1983	608	21	748	27	1697	73
1984	630	22	777	29	1772	75
1985	653	23	807	30	1848	76
1986	677	24	838	31	1926	78
1987	702	25	870	32	2006	80

The method for determining the number of future terminal requirements appears consistent as the ratio of UHF terminal requirements to the total number of UHF requirements does not change (55% in 1981 and 56% in 1987) and the ratio of UHF to VHF terminal requirements also remains constant (70% in 1981 and 71.5% in 1987).

b. Location of Future Requirements

To accurately predict the impact of future frequency requirements, their geographic locations are as important as their number. New en route requirements are usually established to fill holes in coverage and to cover new sectors created when old sectors become too heavily congested with air traffic. Since such changes could be necessary anywhere in the country, the geographic coordinates for future en route requirements were generated at random. Figure 7 is a map showing these locations. New terminal requirements result when new air traffic control towers (ATCT's) are established or when new services are offered at small airports. New terminal requirements would also be established at major airports to relieve congestion on existing frequencies. Again, since new ATCT's and services could be necessary anywhere, locations for these facilities were also generated at random. Locations for new requirements being added at major terminal areas were obtained from assignment data for 60 of the most active terminal facilities. Figures 8 and 9 are maps showing the locations of the major terminals and future small terminal sites. Appendix B contains a list of the locations of 60 new RCAG sites generated at random, the 60 major terminal areas, and the 92 sites generated at random for new ATCT's and services. Geographic locations of future UHF requirements were taken directly from the VHF study since the VHF and UHF facilities for a particular sector are usually collocated.

c. Service Volume Dimensions

Service volume radius and altitude are also important parameters in the assignment process. To simplify the generation of the future frequency environment, all new requirements were assumed to have circular service volumes with the following altitudes and radii:

- | | |
|---------------------------|---|
| 1. High Altitude En Route | 45,000 feet (13500 m) at 100 nmi (184 km) |
| 2. Low Altitude En Route | 18,000 feet (5400 m) at 60 nmi (111 km) |
| 3. Terminals | 13,000 feet (3750 m) at 30 nmi (55 km) |

Service volumes 1 and 2 are of standard dimensions listed in existing FAA frequency assignment documents. Service volume 3 is an average of the standard dimensions for the various types of terminal facilities.

d. Assignment of Future Requirements

Future requirements generated above were added to the data base. These requirements were arranged so that they would be assigned sequentially by year (See Appendix A). In addition to the assumptions made in the study of the existing environment, all assignments performed for the future environment assumed that the existing TSU's and local control (tower) frequencies remained unchanged and non-FAA systems currently using FAA frequencies were eliminated. Strategies similar to those used in the study of the existing environment were then applied to the future environment.

FIGURE 7
Locations of Future RCAG's
(Generated at Random)

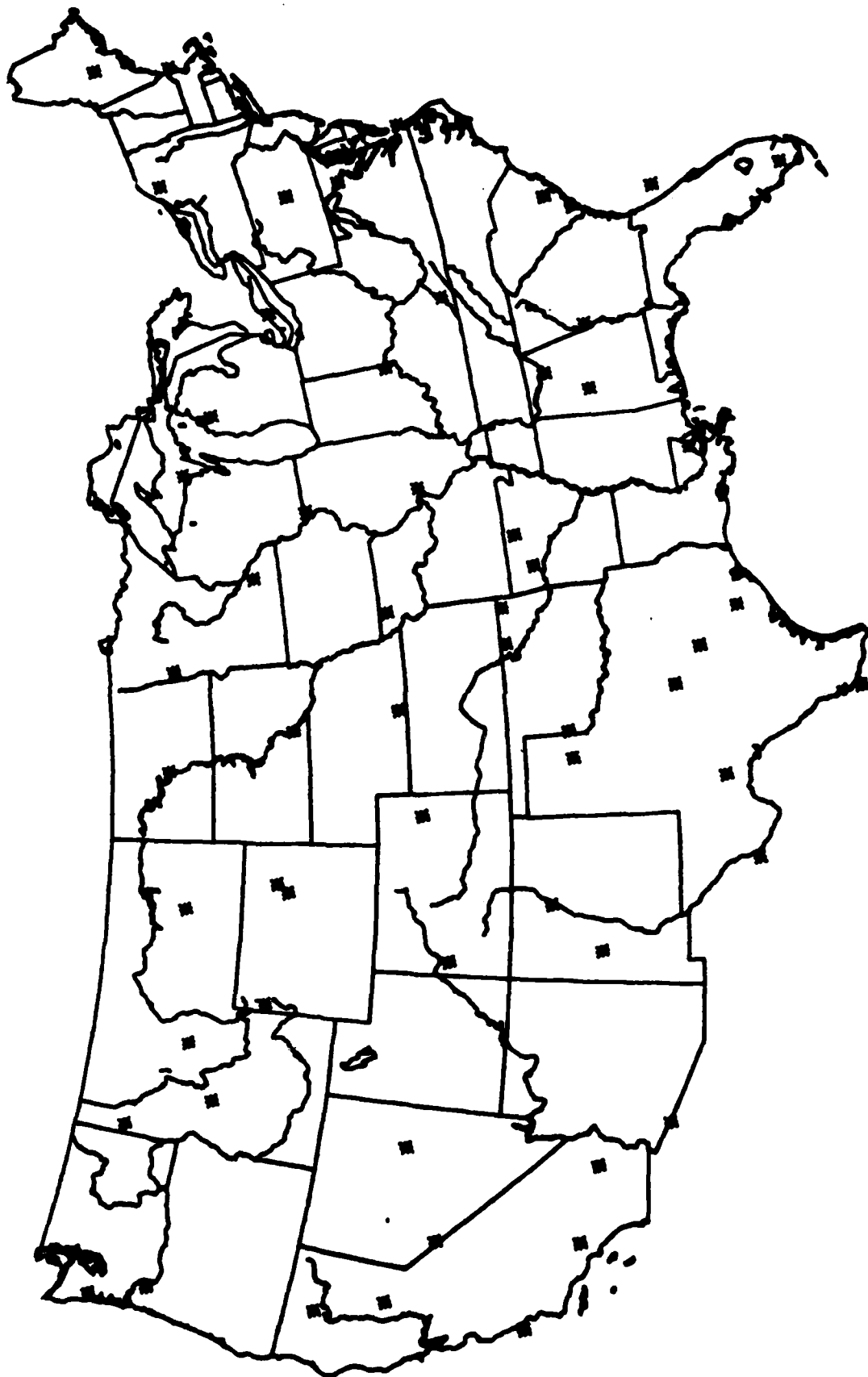


FIGURE 8
Locations of Major Terminal Areas

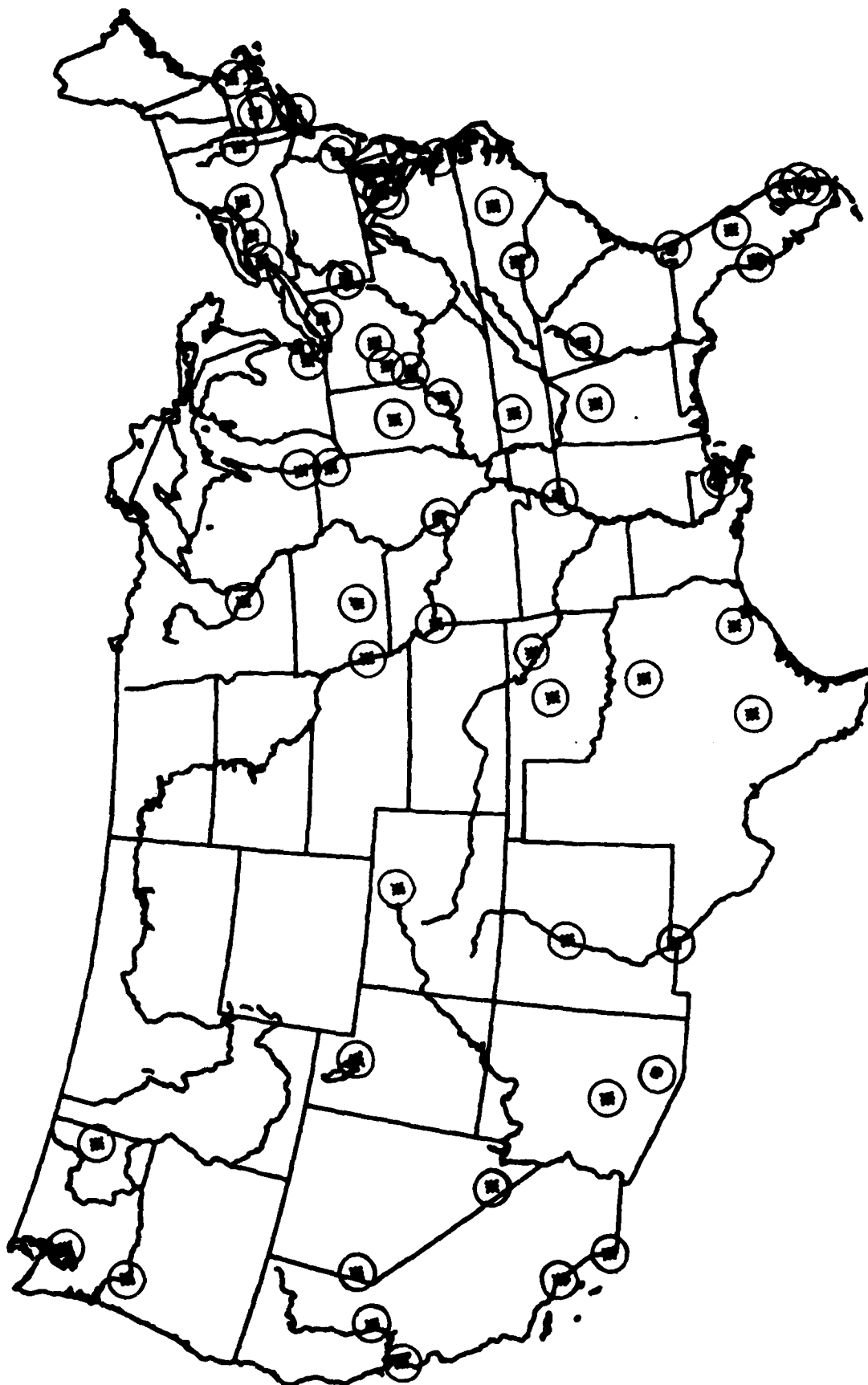
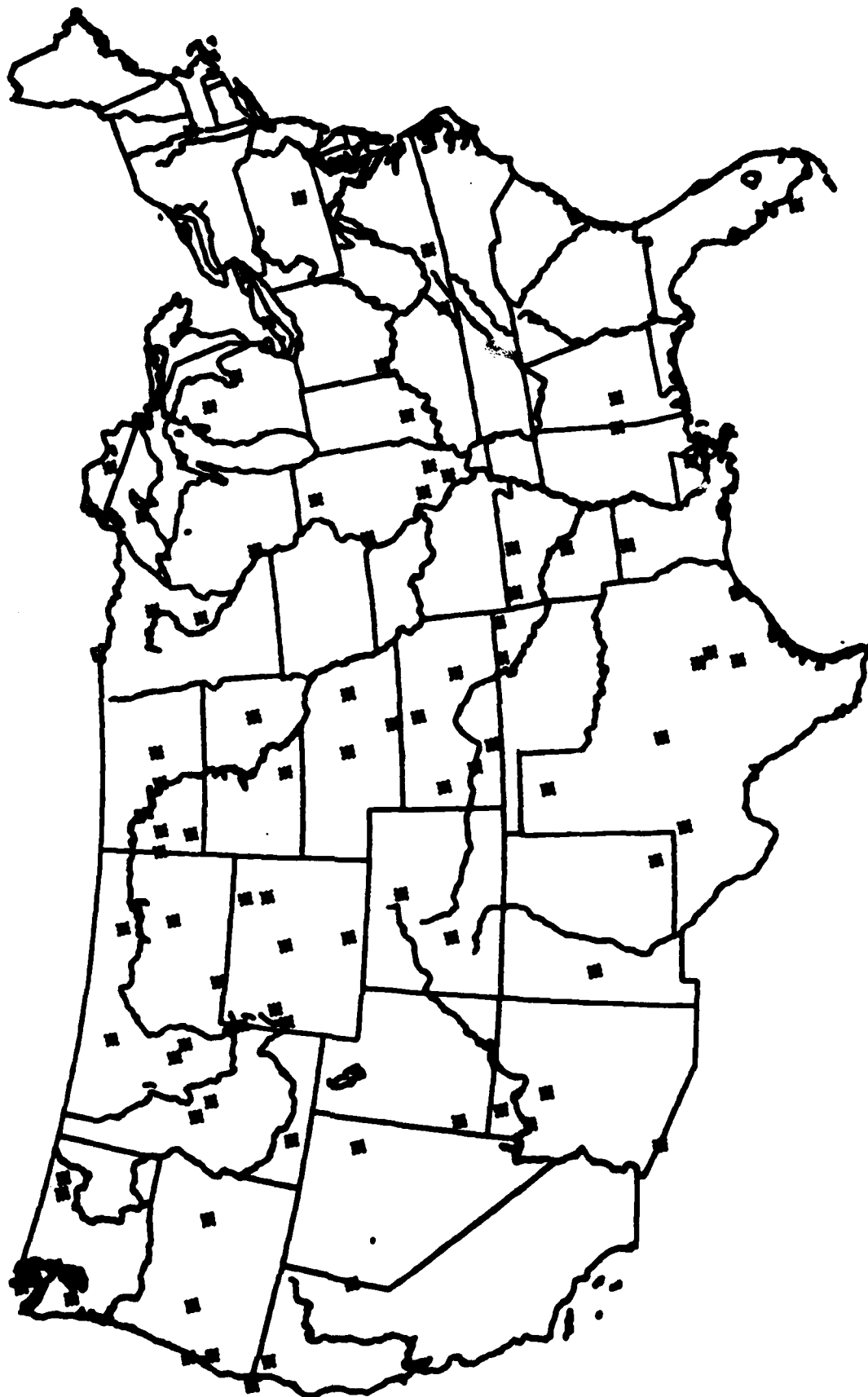


FIGURE 9
Locations of New ATCT's and Services
(Generated at Random)



e. Results

Figure 10 is a compilation of the results obtained.

FIGURE 10
Results of the Study of the Future
Frequency Environment

<u>Assignment Study Number</u>	<u>Description</u>	<u>Requirements To Be Assigned Existing/Future</u>	<u>Number Not Assigned Existing/Future</u>	<u>Number of Channels to Complete</u>
5	All requirements assigned on FAA 100 kHz frequencies Order - H, L, then T	2566/765	1301/695	*
6	All requirements on 274 FAA frequencies Ordering by Density (Similar to Assign #1)	2566/765	362/284	157
7	All requirments on 274 FAA frequencies Order - H, L, T (Similar to Assign #2)	2566/765	56/284	148
8	Same as 7 with 45 future local controls assigned on 257.8 MHz (Similar to Assign #3)	2566/720	50/268	*
9	Same as 7 but non-FAA cosite analysis disabled (Similar to Assign #4)	2566/765	42/278	*

* Value not determined

Assignment #5 was performed to illustrate the severe impact of continuing to restrict assignments to the 132 channels on 100 kHz increments. While the number of additional channels required was not determined directly, it is anticipated that spectrum support of 175 additional channels (ie. in addition to the current 299 channels) would have to be obtained from the military to satisfy the expected growth in frequency assignments. A comparison of Assignments #6 and #7 again shows the improvement in the number of requirements satisfied by assigning en routes before terminals. However, it also shows that as the band becomes more congested, the number of additional channels required is not appreciably reduced by changing assignment order. It was found that all en route requirements were assigned on FAA frequencies,

thus achieving FAA's goal of providing more protection to en route facilities. Assignment #8 shows that the current policy of assigning all local control (tower) facilities on 257.8 MHz also has little impact on the number of additional channels required. It is significant to note that Assignments #6, #7, and #8 each had very nearly the same number of future requirements unassigned and thus about the same number of additional channels were necessary to assign all requirements. This indicates that changes in assignment procedures would have minimal effect on the number of frequencies which can be assigned as the band becomes more congested. Assignment #9 illustrates, as did Assignment #4, the minimal impact of the more extensive cosite model on the spectrum available for assignment.

f. Number of Additional Channels Required Per Year

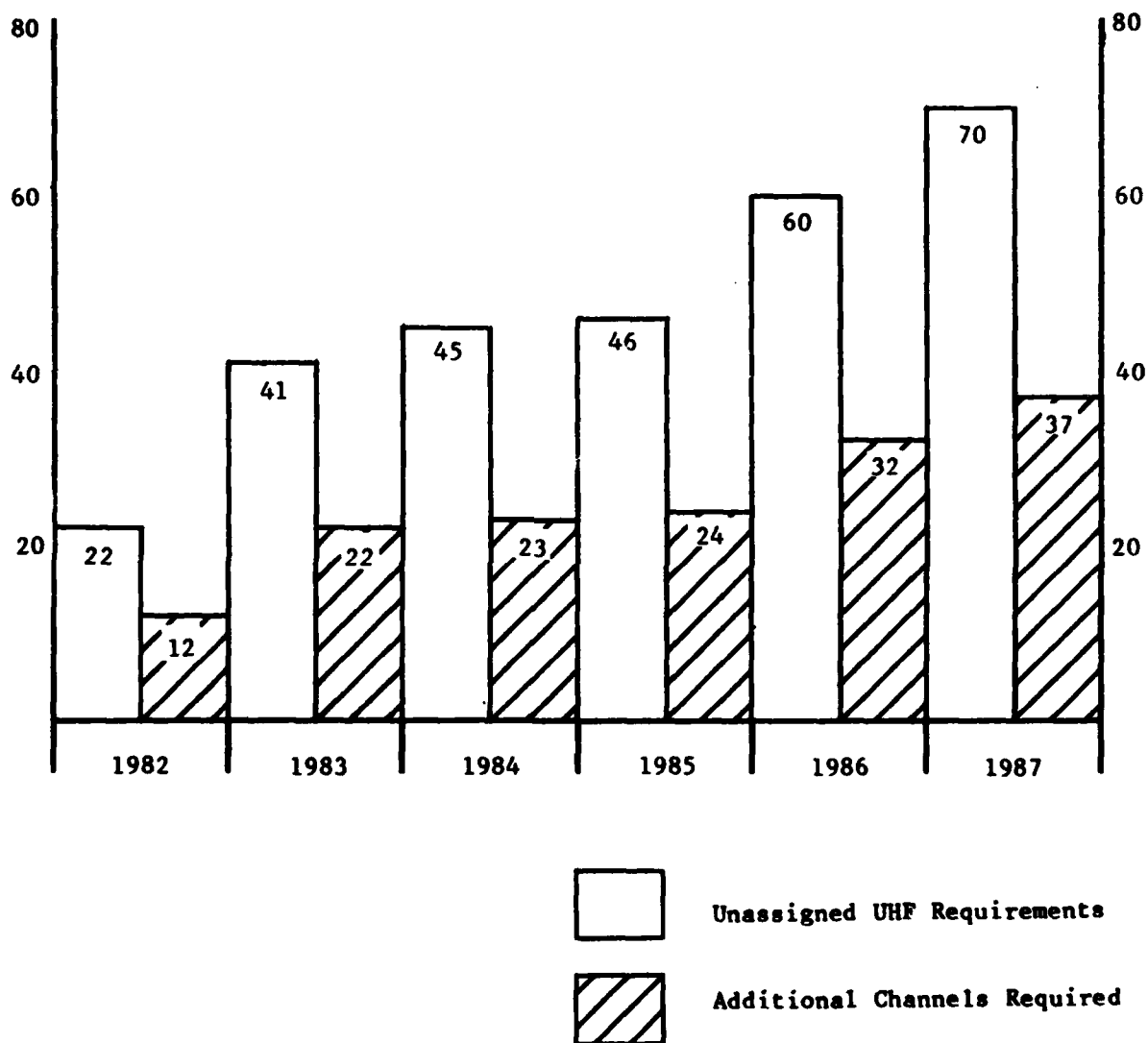
Assignments #6 and #7 indicate that approximately 150 additional channels are required to satisfy 284 unassigned future requirements through 1987. Based on Assignment #7, Figure 11 shows the number of unassigned future requirements each year along with the proportionate number of additional channels necessary each year to satisfy these unassigned requirements.

5. QUALIFICATION OF RESULTS

a. The Assignments performed above are idealized examinations of the existing and possible future frequency environments. There were several possible variables which could not be accounted for which could impact the results of this study. For example, frequency requirements resulting from new services or systems in the band, whether for air traffic control or tactical functions, could not be predicted and may or may not be accounted for in normal growth. Other factors which affect the number of requirements which can be assigned (such as increases in the number of FM and TV broadcasting stations) were not included because information on projected growth in the numbers of these facilities was not available. Such increases in the number of services or systems which affect assignments in the UHF band would serve to increase congestion and complicate problems pointed out by this study.

b. The effect of the air traffic controllers strike in August 1981 on the growth of the system was not included. The FAA has projected that the strike would limit aviation growth for approximately two years after which it would continue to increase at its previous rate [5]. The effect on the results of this study would be to delay each projected date (such as those in Figures 6 and 11) by two years.

FIGURE 11
Number of Unassigned UHF Requirements
And Additional Channels Required
Each Year From 1982 Through 1987
(Based on Assignment #7)



6. CONCLUSIONS AND RECOMMENDATIONS

a. A comparison of the existing FAA usage of the UHF band (Figure 1) and the results of Assignment #5 (from Figure 10) indicates a close correlation between existing FAA usage and results obtained using the computer model with similar constraints (1301 existing requirements not assigned on the 132 FAA frequencies using the computer, versus the actual 1160 requirements assigned on non-FAA frequencies). This correlation is a good indication of the validity of the rest of the assignments performed in this study.

b. If future requirements were assigned using the existing constraints (Assignment #5), nearly all would not be assigned. Currently, additional spectrum support of 299 channels is required to satisfy 1160 unassigned requirements (approximately 4 unassigned requirements per additional channel). If this same ratio is maintained in the future, additional spectrum support of 175 channels (474 channels total) will be required from the military.

c. The anticipated growth in the number of requirements makes the continued use of only the 100 kHz spaced channels impractical. The FAA must make assignments on 50 and 25 kHz spaced channels whenever possible. The FAA must also urge the military to upgrade their airborne equipment as soon as possible if the future demand for assignments is to be met.

d. When all 274 channels allotted to the FAA are available for use, Assignments #6 and #7 show that additional spectrum support from the military of only 150 channels total would be necessary to satisfy all requirements through 1987. This is a considerable improvement over the 474 channels necessary assuming continuation of the existing constraints.

e. The amount of additional spectrum support from the military required will increase each year, thus the assignment of UHF frequencies for air traffic control will become an ever increasing burden on both FAA and DOD frequency management. An automated on-line assignment system similar to that used for VHF assignments, should be developed for the UHF band to alleviate this problem in the near term.

f. With the successful development of the Modular Multi-Function Multi-Band Airborne Radio System (MFBARS), most military aircraft should be capable of using VHF ATC air/ground communications in the 1990's. [8] Therefore, the FAA and DOD should discuss the elimination of ATC air/ground communications from the UHF band as a long term solution to the problem of UHF assignment congestion.

g. The current FAA policy of giving en route facilities preference when assigning UHF frequencies makes efficient use of the spectrum available to the FAA. This policy should be continued. However, the benefit of this policy diminishes as more frequency requirements are added increasing the congestion in the band.

h. The more extensive cosite model used in the UHF system does not overly restrict assignments from a spectrum utilization standpoint. The use of this cosite model provides additional interference protection to UHF assignments and should be incorporated into any on-line system developed.

7. REFERENCES

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- [8] Reilly, R. A., C. W. Ward, A. Lee, R. Schineller, A. Clemens, W. Robertson, and J. Rome, Modular Multi-Function Multi-Band Airborne Radio System (MFBARS), AFWAL-TR-81-1077, Volumes I and II, March 1978 - June 1980.
- [9] Shean, Robert, FAA Frequency Engineering Branch, AAF-730, Private Conversation Concerning Current FAA UHF Frequency Assignments, October 1981.

APPENDIX A UHF CHANNELS ALLOTTED TO THE FAA FOR AIR TRAFFIC CONTROL

Frequencies listed are in MHz.

239.00	269.65	287.90	307.325	327.15	353.60	379.20
239.05	270.25	287.95	307.35	327.80	353.65	379.25
239.25	270.30	288.05	307.375	335.50	353.70	379.90
239.30	270.35	288.10	307.80	335.55	353.75	379.95
239.35	272.70	288.15	307.90	335.60	353.80	380.00
251.05	272.75	288.25	316.05	335.65	353.85	380.05
251.10	273.45	288.30	316.10	338.20	353.90	380.10
251.15	273.55	288.35	316.15	338.25	353.95	380.20
254.25	273.60	290.20	317.40	338.30	354.00	380.20
254.20	275.05	290.25	317.45	338.35	354.05	380.25
254.35	275.15	290.30	317.50	339.80	354.10	380.30
255.40	277.40	290.35	317.55	343.60	354.15	380.35
256.85	278.30	290.40	317.60	343.65	357.60	381.40
256.875	278.85	290.45	317.65	343.70	360.60	381.45
256.90	278.45	290.50	317.70	343.75	360.65	381.50
257.60	278.50	290.55	317.75	343.80	360.70	381.55
257.65	278.55	291.60	319.00	343.85	360.75	381.60
257.70	279.50	291.65	319.10	343.90	360.80	381.65
257.75	279.55	291.70	319.15	343.95	360.85	385.40
257.80	279.60	291.75	319.20	346.25	362.30	385.45
257.85	279.65	298.85	319.25	346.30	362.35	385.50
257.90	281.40	298.90	319.80	346.35	363.00	385.55
257.95	281.45	298.95	319.85	346.40	363.05	385.60
263.00	281.50	299.20	319.90	348.60	363.10	385.65
263.05	281.55	306.20	319.95	348.65	363.15	387.00
263.10	282.20	306.25	322.30	348.70	363.20	387.85
263.15	282.25	306.30	322.35	348.75	363.25	387.10
269.00	282.30	306.90	322.40	350.20	370.85	387.15
269.05	282.35	306.95	322.45	350.25	370.90	397.85
269.10	284.60	307.00	322.50	350.30	370.95	397.90
269.15	284.65	307.05	322.55	350.35	371.85	397.95
269.20	284.70	307.10	323.00	351.70	371.90	398.85
269.25	284.70	307.125	323.05	351.80	371.95	398.90
269.30	285.40	307.15	323.10	351.85	372.00	398.95
269.35	285.45	307.175	323.15	351.90	377.05	
269.40	285.50	307.20	323.20	351.95	377.10	
269.45	285.55	307.225	323.25	352.00	377.15	
269.50	285.60	307.25	327.00	352.05	377.20	
269.55	285.65	307.275	327.05	353.50	379.10	
269.60	287.85	307.30	327.10	353.55	379.15	

APPENDIX B FUTURE FREQUENCY REQUIREMENT LOCATIONS AND ASSIGNMENT SEQUENCE

1. Locations of the Major Terminal Areas

<u>Site #</u>	<u>City/State</u>	<u>Latitude</u>	<u>Longitude</u>
T1	Atlanta, Ga	33 39 28	84 25 33
T2	Boston, Mass.	42 21 55	71 01 06
		42 27 06	71 02 12
T3	Chicago, Ill.	42 00 19	87 54 47
T4	Dallas-Ft Worth, Tex.	32 49 51	97 03 57
T5	Los Angeles, Cal.	33 57 44	118 22 38
T6	Miami, Fla.	25 48 09	80 21 07
T7	New York, NY.	40 48 28	73 05 57
T8	San Francisco, Cal.	37 37 14	122 21 52
T9	Washington, D. C.	38 54 04	77 13 49
T10	Cleveland, Ohio	41 30 55	81 40 55
T11	Denver, Colo.	40 11 00	105 08 00
T12	Detroit, Mich.	42 13 25	83 21 32
T13	Houston, Tex.	29 58 44	95 19 55
T14	Kansas City, Kans.	39 08 37	94 36 34
T15	Las Vegas, Nev.	36 18 00	115 40 00
T16	Minneapolis, Minn.	45 03 37	93 20 39
T17	New Orleans, La.	30 02 35	90 01 33
T18	Philadelphia, Pa.	39 52 33	75 14 41
T19	Pittsburgh, Pa.	40 32 07	80 13 08
T20	Seattle, Wash.	47 31 45	122 18 10
T21	St. Louis, Mo.	38 48 52	90 23 09
T22	Memphis, Tenn.	35 03 01	89 59 01
T23	Orlando, Fla.	28 32 42	81 20 29
T24	Portland, Ore.	45 35 21	122 35 32
T25	Des Moines, Ia.	41 32 30	93 40 23
T26	Spokane, Wash.	47 37 14	117 39 17
T27	Sacramento, Cal.	38 40 20	121 24 37
T28	Rochester, NY.	43 07 01	77 40 01
T29	Jacksonville, Fla.	30 28 32	81 39 10
T30	Tulsa, Okla.	36 13 56	95 54 10
T31	El Paso, Tex.	31 52 00	106 29 30
T32	Tucson, Ariz.	32 06 46	110 57 18
T33	Salt Lake City, Ut.	40 46 43	111 57 21
T34	San Diego, Cal.	32 44 10	117 11 20
T35	Albuquerque, N Mex.	35 00 04	106 36 13
T36	San Antonio, Tex.	29 32 18	98 28 01
T37	Albany, NY.	42 46 40	73 50 20
T38	Ft. Lauderdale, Fla.	26 11 45	80 09 45
T39	Buffalo, NY.	42 58 11	78 45 39
T40	Baltimore, Md.	39 10 14	76 40 22

<u>Site #</u>	<u>City/State</u>	<u>Latitude</u>	<u>Longitude</u>
T41	Cincinnati, Ohio	39 06 30	84 25 28
T42	Charlotte, NCar.	35 14 38	80 57 12
T43	Nashville, Tenn.	36 08 01	86 41 01
T44	Louisville, Ky.	38 13 39	85 39 39
T45	Oklahoma City, Okla.	35 37 10	97 38 24
T46	Omaha, Neb.	41 18 38	95 54 28
T47	Windsor-Locks, Conn.	41 58 22	72 41 31
T48	Dulles, Vir.	38 58 31	77 26 42
T49	Columbus, Ohio	40 04 30	83 04 15
T50	Dayton, Ohio	39 48 22	84 05 52
T51	Norfolk, Vir.	36 56 21	76 17 43
T52	Syracuse, NY.	43 08 35	76 06 51
T53	Raleigh-Durham, NCar.	35 38 01	78 40 30
T54	Birmingham, Ala.	33 33 57	86 45 04
T55	Milwaukee, Wis.	42 55 38	87 53 53
T56	Indianapolis, Ind.	39 49 47	86 17 41
T57	West Palm Beach, Fla.	26 40 43	80 10 55
T58	Reno, Nev.	39 29 38	119 45 59
T59	Tampa, Fla.	27 59 51	82 32 35
T60	Phoenix, Ariz.	33 25 40	112 01 13

2. Locations of New Air Traffic Control Towers or New Services

<u>Site #</u>	<u>Latitude</u>	<u>Longitude</u>
1.	43 06 11	110 40 55
2.	37 48 43	89 10 45
3.	38 37 42	89 39 49
4.	42 34 14	79 40 34
5.	35 50 53	113 28 00
6.	41 37 15	99 42 06
7.	40 23 07	91 08 46
8.	32 28 37	88 28 38
9.	48 09 05	107 30 09
10.	46 20 57	103 09 29
11.	41 33 18	97 20 27
12.	41 56 30	124 35 20
13.	38 28 35	106 55 45
14.	37 17 18	99 38 02
15.	41 56 02	89 21 20
16.	37 00 15	80 26 37
17.	32 33 27	104 02 23
18.	41 30 13	107 05 58
19.	40 01 01	120 03 50
20.	47 21 14	123 32 58

<u>Site #</u>	<u>Latitude</u>	<u>Longitude</u>
21.	29 46 43	97 13 36
22.	30 35 01	96 51 34
23.	43 12 19	123 56 37
24.	43 47 56	124 17 21
25.	37 50 02	100 29 03
26.	42 28 36	115 15 46
27.	38 19 53	88 42 06
28.	47 14 01	88 54 31
29.	44 37 49	105 49 26
30.	47 16 22	93 13 00
31.	42 52 34	73 13 55
32.	45 57 38	112 08 45
33.	25 47 34	82 02 43
34.	43 21 28	107 37 04
35.	44 06 51	122 20 14
36.	35 28 15	112 18 50
37.	31 40 17	102 55 47
38.	36 41 38	113 04 24
39.	48 04 35	112 27 24
40.	44 19 38	118 57 17
41.	46 40 59	106 58 34
42.	32 12 51	99 43 38
43.	36 58 33	82 46 06
44.	37 49 55	113 38 16
45.	47 14 49	103 59 29
46.	46 11 25	112 44 46
47.	38 16 35	96 50 53
48.	35 40 53	101 22 22
49.	34 18 41	107 55 45
50.	39 10 41	84 25 17
51.	43 58 53	91 06 11
52.	30 58 48	97 12 48
53.	44 37 13	84 40 28
54.	38 43 47	86 34 32
55.	44 35 22	106 13 05
56.	36 10 42	92 18 23
57.	39 27 40	98 24 27
58.	32 42 47	92 45 51
59.	47 23 48	99 34 50
60.	45 13 52	109 21 43

<u>Site #</u>	<u>Latitude</u>	<u>Longitude</u>
61.	36 51 33	96 25 06
62.	30 27 23	90 04 48
63.	44 23 31	111 02 13
64.	43 39 37	83 36 55
65.	40 35 04	115 04 59
66.	43 58 45	105 42 51
67.	48 34 20	118 46 55
68.	47 14 42	103 04 09
69.	40 01 26	105 18 55
70.	45 49 54	93 44 26
71.	36 14 45	93 59 49
72.	42 17 22	81 44 05
73.	38 46 33	101 11 01
74.	36 51 04	95 03 33
75.	43 31 54	100 29 55
76.	41 41 01	123 32 46
77.	32 09 46	113 45 54
78.	40 14 35	98 40 11
79.	47 17 00	100 55 59
80.	37 10 46	94 49 56
81.	44 25 50	98 08 57
82.	44 56 07	114 17 05
83.	32 21 31	87 25 29
84.	40 21 31	77 09 25
85.	34 34 06	92 32 27
86.	48 47 10	123 48 36
87.	48 29 16	119 27 11
88.	42 23 23	81 49 17
89.	41 35 25	123 24 07
90.	45 16 13	115 00 11
91.	43 28 35	110 14 03
92.	47 59 13	86 30 42

3. Location of Future RCAG Sites.

<u>RCAG #</u>	<u>Latitude</u>	<u>Longitude</u>
R 1.	38 17 49	118 49 38
R 2.	47 02 11	96 26 57
R 3.	40 21 55	94 42 37
R 4.	45 51 47	123 01 27
R 5.	44 18 25	92 43 02
R 6.	39 05 56	77 19 18
R 7.	30 31 02	101 49 51
R 8.	35 04 12	100 54 22
R 9.	44 06 37	110 44 31
R10.	44 44 52	85 27 24
R11.	29 39 48	104 44 38
R12.	34 23 12	86 29 55
R13.	47 35 25	116 37 53
R14.	47 20 41	123 56 27
R15.	29 43 58	95 55 29

<u>PCAG #</u>	<u>Latitude</u>	<u>Longitude</u>
R 16	42 46 46	70 37 12
R 17.	39 39 25	102 52 23
R 18.	35 48 43	106 17 59
R 19.	42 26 02	90 12 10
R 20.	35 44 01	93 33 02
R 21.	43 27 57	99 19 21
R 22.	40 46 16	77 17 37
R 23.	39 31 00	115 36 53
R 24.	44 21 21	75 14 17
R 25.	38 47 26	108 30 40
R 26.	36 49 07	75 52 27
R 27.	41 09 08	73 01 43
R 28.	39 21 09	121 18 48
R 29.	41 12 01	122 13 24
R 30..	35 08 28	99 54 48
R 31.	34 05 03	115 25 51
R 32.	33 07 28	87 21 42
R 33.	29 51 01	80 39 45
R 34.	43 39 22	106 04 08
R 35.	35 27 29	121 16 03
R 36.	26 15 57	99 09 40
R 37.	32 51 18	84 59 26
R 38.	45 57 40	87 46 27
R 39.	39 09 40	84 58 14
R 40.	38 53 36	89 54 32
R 41.	31 51 35	98 30 07
R 42.	45 16 13	115 00 11
R 43.	47 17 00	100 55 59
R 44.	40 14 35	98 40 11
R 45.	32 09 46	113 45 54
R 46.	36 51 04	95 03 33
R 47.	42 17 22	81 44 05
R 48.	43 58 45	105 42 51
R 49.	30 27 23	90 04 48
R 50.	36 51 33	96 25 06
R 51.	36 10 42	92 18 23
R 52.	30 58 48	97 12 48
R 53.	34 18 41	107 55 45
R 54.	46 11 25	112 44 46
R 55.	36 58 33	82 46 06
R 56.	46 40 59	106 58 34
R 57.	44 56 18	69 32 24
R 58.	33 09 16	80 01 48
R 59.	34 20 02	118 05 56
R 60.	25 50 42	80 58 30

4. UHF Requirements Added to the Data Base by Year.

Year	Number of New Frequencies Per Site	Function	Site #	Total for Year
1982	2	High En Route	R21-R30	119
	1	High En Route	R31	
	2	Low En Route	R25-R37	
	1	Terminal	T1-T60	
	1	Terminal	25-36	
1983	1	High En Route	R31	121
	2	High En Route	R32-R41	
	2	Low En Route	R38-R50	
	1	Low En Route	R51	
	1	Terminal	T1-T60	
	1	Terminal	39-51	
1984	2	High En Route	R42-R52	126
	1	Low En Route	R51	
	2	Low En Route	R52-R60	
	1	Low En Route	R1-R9	
	1	Low En Route	R10	
	1	Terminal	T1-T60	
	1	Terminal	55-69	
1985	2	High En Route	R53-R60	129
	2	High En Route	R12-R14	
	1	High en route	R15	
	2	Low En Route	R16-R30	
	1	Terminal	T1-T60	
	1	Terminal	73-88	
1986	1	High En Route	R15	133
	2	High En Route	R16-R26	
	1	High En Route	R27	
	2	Low En Route	R31-R45	
	1	Low En Route	R46	
	1	Terminal	T1-T60	
	1	Terminal	1-18	
1987	1	High En Route	R27	137
	2	High En Route	R28-R39	
	2	Low En Route	R46-R60	
	2	Low En Route	R1	
	1	Terminal	T1-T60	
	1	Terminal	19-38	

APPENDIX C ACRONYMS

ACES	-	Adaptation Controlled Environment System
ARINC	-	Aeronautical Radio Incorporated
ATC	-	air traffic control
ATCT	-	air traffic control tower
Com/Nav	-	Communication and Navigation
DOD	-	Department of Defense
ECAC	-	Electromagnetic Compatibility Analysis Center
FAA	-	Federal Aviation Administration
FCC	-	Federal Communications Commission
FM	-	frequency modulation
FSS	-	Flight Service Station
GMF	-	Government Master File
H	-	High Altitude En Route
IRAC	-	Interdepartment Radio Advisory Committee
kHz	-	kiloHertz
km	-	kilometer
L	-	Low Altitude En Route
MCEB	-	Military Communications and Electronics Board
MHz	-	MegaHertz
NAS	-	National Airspace System
nmi	-	nautical mile
RCAG	-	Remote Communications Air Ground
T	-	Terminal
TSU	-	High Altitude Tactical Special Use
TV	-	television
UHF	-	Ultra High Frequency
VHF	-	Very High Frequency